Transportation System Sustainability Issues in High-, Middle-, and Low-Income Economies: Case Studies from Georgia (U.S.), South Korea, Colombia, and Ghana

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Abstract: While there is no standard definition for sustainable transportation, several adopted definitions reflect that a sustainable transportation system should be effective and efficient in providing safe and equitable access to basic economic and social services, promote economic development and support environmental integrity. Critical priorities, standards, and constraints for attaining sustainable transportation may be different, however, in different countries depending on prevailing socioeconomic conditions and political and administrative institutions. This study develops four case studies to characterize some of the major transportation system sustainability issues in developed and developing economies. The cases demonstrate that while transportation sustainability issues revolve around similar issues, the actual process of identifying and addressing pertinent issues to promote transportation system sustainability may involve widely different priorities and constraints that should influence how standards are developed to promote successful movement toward sustainability in the international community.

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Introduction

Background

The fact that sustainability is an increasingly important issue in transportation system and services provision is evident in congested metropolitan highway systems, declining air quality and respiratory health, the need for improved and more equitable access to basic social and economic services in several areas around the world, and a growing number of initiatives to address sustainability considerations in transportation planning. Sustainable development is most commonly defined as *development that meets the needs of the present without compromising the ability of future generations to meet their own needs* (WCED 1987). While there is no standard definition for a sustainable transportation system, there is emerging consensus that such a system should be effective and efficient in providing its users with equitable and safe access to basic social and economic services, should promote economic development, and not be harmful to the environment—and indicator systems being developed and used reflect this consensus (Jeon and Amekudzi 2005). Major organizations such as the World Bank, the Organization for Cooperation and Economic Development (OECD), and Transport Canada have adopted definitions for sustainable transportation. The OECD, for example, defines sustainable transportation as *transportation that does not endanger public health or ecosystems and meets the needs for access consistent with (a) the use of renewable resources at or below their rates of regeneration, and (b) the use of nonrenewable resources below the rates of development of renewable substitutes* (OECD 1999). Table 1 shows several working definitions of sustainable transportation and sustainability. In the United States, the mission statements of over 14 state departments of transportation (DOTs) now include sustainability either explicitly or implicitly (Jeon and Amekudzi 2005). In addition, a growing number of organizations around the world have begun to develop and use indicator systems to measure their progress toward transportation system sustainability.

Motivation

While sustainable transportation is a policy objective or issue of concern in high-, middle-, and low-income countries, critical factors influencing the attainment of a sustainable transportation/land use system, the relative priorities accorded various sustainability objectives, and the constraints to be encountered in moving transportation systems toward sustainability, may be different in these different environments. Discussions on sustainable transportation that remain at a relatively general level may not shed adequate light on unique issues and priorities that must be addressed relative to attaining sustainable transportation in different socioeconomic contexts. More-detailed assessments are necessary to

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Table 1. Working Definitions of Sustainability (Transportation and General)

Organization	Definitions of sustainable transportation and sustainability
Ontario Roundtable on Environment and Economy 1995 (Canada)	(1) Produce outputs (emissions) at a level capable of being assimilated by the environment. (2) Have a low need for inputs of non-renewable resources (where nonrenewable are used, their use will be for non-consumptive investments and they will be recycled when no longer useful or needed). (3) Minimize disruption of ecological processes, land (and water area) use is also minimized as well as uses of sensitive habitats.
Transportation Association of Canada 1999 (Canada)	(1) In the *natural environment*: limit emissions and waste (that pollute air, soil, and water) within the urban area's ability to absorb/recycle/cleanse; provide power to vehicles from renewable or inexhaustible energy sources (such as solar power in the long run); and recycle natural resources used in vehicles and infrastructure (such as steel, plastic, etc.). (2) In *society*: provide equity of access for people and their goods, in this generation and in all future generations; enhance human health; help support the highest quality of life compatible with available wealth; facilitate urban development at the human scale; limit noise intrusion below levels accepted by communities; and be safe for people and their property. (3) In the *economy*: be financially affordable in each generation; be designed and operated to maximize economic efficiency and minimize economic costs; and help support a strong, vibrant and diverse economy.
Victoria Transport Policy Institute 2003 (Canada)	Providing for a secure and satisfying material future for everyone, in a society that is equitable, caring, and attentive to basic human needs.
The Center for Sustainable Transportation 2002 (Canada)	(1) Allows the basic access needs of individuals and societies to be met safely and in a manner consistent with human and ecosystem health, and with equity within and between generations. (2) Is affordable, operates efficiently, offers choice of transport mode, and supports a vibrant economy. (3) Limits emissions and waste within the planet ability to absorb them, minimizes consumption of non-renewable resources, reuses and recycles its components, and minimizes the use of land and the production of noise.
Organization for Economic Cooperation and Development 1999	Environmentally sustainable transportation is defined as: "Transportation that does not endanger public health or ecosystems and that meets needs for access consistent with (a) use of renewable resources at below their rates of regeneration, and (b) use of nonrenewable resources below the rates of development of renewable substitutes."
World Bank	General operational principles for physically sustainable societies (not especially for the transport sector) is defined as: "Their rates of use of renewable resources do not exceed their rates of regeneration. Their rates of use of nonrenewable resources do not exceed the rate at which substitutes are developed. Their rates of pollution do not exceed the assimilative capacity of the environment."
Procedures for Recommending Optimal Sustainable Planning of European City Transport Systems 2003	A sustainable urban transport and land use system: (1) provides access to goods and services in an efficient way for all inhabitants of the urban area; (2) protects the environment, cultural heritage and ecosystems for the present generation, and (3) does not endanger the opportunities of future generations to reach at least the same welfare level as those living now, including the welfare they derive from their natural environment and cultural heritage.
Department of Sustainable Development 2003 (United Kingdom)	Sustainable development is about ensuring a better quality of life for everyone, now and for generations to come. This requires meeting four key objectives at the same time in the U.K. and the world as a whole: (1) social progress which recognizes the needs of everyone; (2) effective protection of the environment; (3) prudent use of natural resources, and (4) maintenance of high and stable levels of economic growth and employment.

Note: Adapted from Jeon and Amekudzi (2005).

understand the drivers of existing transportation systems better, as well as priorities and constraints for attaining sustainable transportation across the range of socioeconomic conditions in the global community.

Objective and Outline

The objective of this study is to characterize some of the major issues in transportation sustainability in high-, middle-, and low-income economies. This is done through the development of four case studies for selected countries/states with a range of economic conditions: Georgia (United States, high-income status), South Korea (East Asia, recently moved from middle- to high-income status), Colombia (South America, middle-income status), and Ghana (West Africa, low-income status). The purpose is threefold. First, it is to demonstrate that while definitions of sustainable transportation seem to revolve around system effectiveness

and efficiency, safe and equitable access, economic development, and environmental integrity, the actual process of addressing sustainability in transportation system and services provision may involve widely different priorities, standards, and constraints. Second, it is to emphasize that there are no universal drivers and so indicator systems for transportation sustainability and that the relative effectiveness of any indicator system is a function of how well it monitors progress toward the particular vision and standards it was intended to support. Third, it is to show that the development of definitions, visions, and indicator systems are useful starting points yet incomplete endeavors in any formal approach to consider sustainability in transportation planning. Gudmundsson emphasizes this need to link indicator systems with actual policies based on a study that evaluates six sustainability indicator systems (Gudmundsson 2003). Given the widely different pressures, socioeconomic conditions, and institutional constraints that exist in different contexts, adopting visions and indicators without explicitly identifying, implementing, and monitoring realistic policies to promote movement toward these visions would at best have limited effectiveness.

The next section presents four case studies for countries/states with very different socioeconomic, political, and institutional contexts to characterize major issues relative to achieving transportation sustainability, and the local contexts in which progress toward sustainability must occur. The discussion that follows highlights the importance of developing specific priorities, policies, and standards to address transportation sustainability based on a system-level understanding of the socioeconomic, political, and institutional contexts of the country or other jurisdiction under consideration.

Transportation Issues in Georgia (United States), South Korea, Colombia, and Ghana

Because the quality of transportation affects and is affected by the economy, priorities, standards, and constraints for sustainable transportation may differ, sometimes significantly, depending on the level of socioeconomic development in a country. The World Bank classifies countries as high, middle, or low income based on their gross national income (GNI) per capita. GNI (formerly, gross national product or GNP) is the sum of the value added by all resident producers plus any product taxes (less subsidies) not included in the valuation of output plus net receipts of primary income (Nationmaster.com 2004). According to the World Bank Classification (The World Bank Group 2002), low-income economies are defined as those having a per capita GNI of less than $735; lower- to middle-income countries: $736–$2,935; upper-to-middle-income: $2,936–$9,075; and high-income countries: more than $9,076 per capita. Low- and middle-income economies are sometimes referred to as developing economies, while high-income economies are referred to as developed economies. While the GNI, a broad measure, is considered to be the best single indicator of economic capacity and progress, it is recognized that the GNI does not by itself constitute or measure welfare or success in development (The World Bank Group 2002).

Below, four case studies highlight the status of transportation in various economies: the state of Georgia (United States), high income; South Korea (East Asia), high-income/recently middle income; Colombia (South America), middle income; and Ghana (West Africa), low income. These cases were selected to cover the range of economic categories given by the World Bank Classification. The writers' backgrounds were also relevant in selecting the particular geographic locations as they considered it important to have first-hand knowledge of the systems in each case. The state of Georgia was selected rather than the entire United States for comparability with the other cases, based on population and physical size. While the cases are by no means exhaustive, every attempt was made to ensure that the data, obtained from secondary sources, adequately represent the systems.

Georgia (United States)

Background

Georgia is a state in the southern United States (U.S.), the world's fourth largest nation in land area (after Russia, Canada, and China), extending from the Atlantic coast to the Pacific Ocean and sharing land borders with Canada in the north and Mexico in the south (About 2004). The country has 50 locally autonomous states with a total population of 290 million (2004), and a per capita GNI of U.S.$33,684 (2003) (Nationmaster.com 2004). It has the second largest (after the European Union) and most technologically advanced economy in the world. U.S. firms are at or near the forefront in technological advances, especially in computer, medical, aerospace, and military equipment. Although the country has rich mineral resources and various agricultural products, the biggest sector is service industries, employing about 75% of U.S. residents.

With a land area of 57,906 sq mi (149,976 km^2), Georgia is the largest state east of the Mississippi River (24th overall). Atlanta, the state's capital, is the largest city followed by Savannah, one of the busiest ports in the United States. Based on the 2000 census, the population of Georgia was just over 8 million, making it the 10th most populous state. Nearly half of the state's population lives in the Atlanta metropolitan area, which has experienced phenomenal growth in the past decade. From 1990–2000, Georgia's population grew by over 20%, as shown in Table 2. Georgia's 1999 total gross state product of $275 billion placed it at 10th in the nation, and its per capita personal income of $28,145 placed it at 23rd in the nation in 2000. Service sector employment accounted for about 26% of the state's jobs, followed by retail with about 18%, and government with about 15%. The state's industrial outputs are textiles and apparel, transportation equipment, food processing, paper products, chemical products, electric equipment, and tourism. Agriculture also plays a major role in the state's economy, contributing about five billion dollars annually (Wikipedia 2004).

Transportation System

General Characteristics. As in several metropolitan areas around the world, the automobile is the dominant mode of transportation in the Atlanta Metropolitan Area. In 2002, the Atlanta Regional Commission (ARC), the region's Metropolitan Planning Organization, recorded a mode share of home-based work trips at 91.78%, with single occupancy vehicle share at 80.72%, carpool share at 11.06%, and public transit share at 8.22% (ARC 2002). Highways are thus the predominant infrastructure for transportation. In 2002, Georgia's transportation system encompassed 113,655 mi (182,910 km) of public roads, 4,853 mi (7,810 km) of railroad, 103 publicly owned airports, and four shipping ports. Georgia is also served by 12 urban transit systems including the Metropolitan Atlanta Rapid Transit Authority, which serves Atlanta, and 82 rural transit systems (GDOT 2002).

Like several metropolitan areas around the world, Metro At-

Table 2. Population and Vehicle Ownership in Georgia (United States) 1990-2002

	Population		Vehicle	
Year	Number (thousands)	Annual increase (%)	Number (thousands)	Annual increase (%)
1930	2,908,506	—	NA	NA
1940	3,123,723	7.40	NA	NA
1950	3,444,578	10.27	NA	NA
1960	3,943,116	14.47	NA	NA
1970	4,589,575	16.39	NA	NA
1980	5,463,105	19.03	NA	NA
1990	6,478,216	18.58	NA	NA
1991	6,621,279	2.21	NA	NA
1992	6,759,474	2.09	NA	NA
1993	6,894,092	1.99	NA	NA
1994	7,045,900	2.20	NA	NA
1995	7,188,538	2.02	6,192,515	NA
1996	7,332,225	2.00	6,356,164	2.64
1997	7,486,094	2.10	6,317,832	−0.60
1998	7,636,522	2.01	6,979,592	10.47
1999	7,788,240	1.99	7,059,719	1.15
2000	8,186,453	5.11	7,243,077	2.60
2001	—	21.60 (1990-2000)	7,396,731	2.12

Note: NA=not available. Data adapted from the Intermodal Transportation Database Homepage (2000) and U.S. Census Bureau Homepage (2000).

Table 3. Vehicle Miles Traveled and Motor Vehicle Crashes (Georgia, 1990–2002)

				Fatalities and Injuries (person)			
Year	Millions VMT (VKT)	Annual increase rate (%)	Crashes (number)	Fatalities	Fatalities (per 100 million VMT)	Injuries	Total
1990	72,648 (116,916)		228,163	1,564	2.15	98,933	100,497
1991	72,937 (117,381)	0.4	218,766	1,393	1.91	96,748	98,141
1992	77,569 (124,835)	6.4	231,122	1,324	1.71	102,951	104,275
1993	77,886 (125,345)	0.4	242,093	1,407	1.81	109,350	110,757
1994	82,780 (133,221)	6.3	270,688	1,437	1.74	135,731	137,168
1995	85,280 (137,245)	3.0	283,639	1,492	1.75	139,857	141,349
1996	88,888 (143,051)	4.2	298,247	1,582	1.78	142,864	144,446
1997	93,268 (150,100)	5.0	301,767	1,584	1.70	139,386	140,970
1998	96,607 (155,474)	3.6	293,251	1,579	1.63	133,034	134,613
1999	98,913 (159,185)	2.4	NA	1,514	1.53	NA	NA
2000	104,723 (168,535)	5.9	309,334	1,548	1.48	127,177	128,725
2001	107,974 (173,767)	3.1	317,851	1,621	1.50	129,431	131,052
2002	108,300 (174,292)	0.3	328,272	1,532	1.41	132,913	134,445

Note: NA=not available. Data adapted from the Georgia Department of Public Safety (2004) and GDOT (2004).

lanta faces severe congestion, with the associated air quality and respiratory health issues. Rapid population and a booming economy have contributed to increasing traffic congestion and reduced air quality in the Metro Area. To control traffic congestion and air pollution, Georgia Department of Transportation (GDOT) has developed a high-tech intelligent transportation system (ITS): the NAVIGATOR, which monitors more than over 200 miles of highway through the use of state-of-the-art video cameras, changeable message signs, and data management technologies to relay real-time traffic conditions 24 h a day to a transportation management center. Complementing the system is GDOT's network of highway emergency response operators (HERO): incident response units with specially trained personnel who can deal quickly with accidents and disabled vehicles. HEROs are important not only for their emergency services but for congestion management as well because in Metro Atlanta, while slightly under half (48%) of the congestion delay is normal recurring (volume related), slightly over half (52%) is from nonrecurring (incident-related) delay. Other measures to manage congestion include 90 mi of high-occupancy vehicle (HOV) lanes, 88 park and ride lots, and 2,943 mi of bicycle and pedestrian routes (GDOT 2004).

System Effectiveness. Approximately half of Georgia's population, 50% of the vehicle-miles-traveled (VMT) and 75% of the congestion in the state occur in Metro Atlanta (GDOT 2001). Vehicle ownership in the state has continued to rise since the mid-1990s, as shown in Table 3. The resulting roadway congestion and traffic delay have been estimated to cost Metro Atlantans 101 million person hours of delay every year, equating to $2 billion in total delay costs annually. According to the Texas Transportation Institute, the travel time index (traffic delay and congestion costs) has increased over 26% in the past 8 years and Metro Atlanta has the 11th most congested freeway system in the United States (TTI 2004). At the same time, VMT in Georgia has been growing rapidly at an annual rate of 3.4% since 1990 and has approximately doubled during the past two decades. Accommodating this rapid growth by maintaining a first class roadway network and providing transportation choices has been and will continue to be the major challenge facing the State (GDOT 2004). Rapid population growth and urban sprawl have exacerbated the congestion problem. Despite Georgia's growing population and dependence on automobile transportation, the state's transit systems have been utilized at a declining rate per capita in the past 10 years (ASCE 2004). Compared with the rest of the country, Georgia's per capita transit system usage is below the national average. Table 4 depicts the decreases in transit ridership and transit system effectiveness for urban and rural transit systems in Georgia between 2000 and 2002.

Safety. The safety of Georgia's roads is average, relative to other U.S. states. There were 1,621 fatalities in 2002, which translates to a fatality rate of 1.50 fatalities per 100 million VMT (the U.S. average is 1.51 fatalities per 100 million VMT) (GDOT 2001). Trends in VMT and the relative number of crashes, fatalities, and injuries, show that safety has been steadily improving over the past decade. However, a considerable portion of the state's fatality crashes have occurred on rural roads, especially on

Table 4. Georgia Urban and Rural Transit System Ridership, 2000–2002

	FY 2000		FY 2002	
Transit system	Ridership (population)	Effectiveness[a]	Ridership (population)	Effectiveness
Urban				
All but Marta	12,856,803 (2,535,590)	5.1	13,006,678 (2,629,114)	4.9
Marta	166,915,560 (1,458,484)	114.4	159,145,301 (1,457,372)	109.2
Sub Total	179,772,363 (3,994,074)	45.0	171,853,917 (4,086,486)	42.1
Rural	1,680,049 (4,192,479)	0.4	1,642,655 (4,473,824)	0.3
Total	181,452,412 (8,186,453)	22.2	173,496,572 (8,560,310)	20.3

Note: Data adapted from the Georgia Department of Transportation (2003); the Georgia Department of Transportation (2004); and the U.S. Census Bureau (2000).

[a]Effectiveness of these transit systems is calculated by dividing ridership by population.

two-way roads, making highway safety in rural areas a major issue in the state. Based on 2001 statistics, four out of 10 crash deaths occurred on rural roads, and seven out of 10 fatalities occurred on two-way roads without any physical separation or barrier (Governor's Office of Highway Safety 2004).

Congestion/Air Quality. Atlanta is currently designated as a nonattainment area for ozone and will be designated as a nonattainment area for particulate matter out of the six pollutants for which the Clean Air Act establishes standards (ASCE 2003). As shown in Table 5, Georgia ranks relatively high for statewide anthropogenic emissions. In the past several years, however, there have been reductions in the number of ozone exceedance days in Atlanta from a high of 23, which occurred in 1999 to a low of 1, which occurred in 2003, as shown in Table 6. Various measures have been taken to aid in controlling the precursors to ozone formation, including a strict vehicle inspection program, controls on emission sources, and the establishment of a voluntary pollution outreach program called the Clean Air Campaign (AAA and Georgia Regional Transportation Authority 2002).

Social Equity/Other Issues. Social equity issues in transportation include equitable access to major social and economic centers for all Georgia's residents, as well as equitable levels of safety on the urban and rural portions of Georgia's highway system. Following a federal executive order (EO 12898) in 1994 for addressing equity (environmental justice) in the decision making process, GDOT has taken several measures to improve capabilities for addressing equity in transportation planning. Environmental justice is part of the Department's planning process and project development considerations. GDOT is in the process of developing a template for planning and project evaluations that will measure, among other things, the benefits and burdens of transportation projects on low income and racial minority communities (GDOT 2004).

Table 5. Georgia Statewide Anthropogenic Emissions and Rank (1998)

Emissions	CO	NO_x	VOC	SO2	PM10	PM2.5	NH3
Thousands (short tons)	3,998	730	576	660	1,103	320	106
Rank out of the 51 states	4	12	9	13	7	4	17

Note: Data adapted from US EPA (2000).

Table 6. Exceedances of Federal Air Quality Standards in Georgia (Atlanta)

Year	Ozone 8 h average (O_3 ppmv)	Ozone 1 h average (O_3 ppmv)[a]	Sulfur dioxide (SO_2 ppmv)
1996	0	7 (7)	0
1997	0	12(11)	0
1998	120(62)	24(22)	9
1999	129(69)	28(23)	0
2000	101(46)	16(11)	0
2001	40(20)	5 (3)	1
2002	64(37)	8 (8)	0
2003	23(13)	1 (1)	0

Note: Data adapted from the Georgia Department of Natural Resources (2004).

[a]EPA recently revised the ozone standard for areas of the state that are outside the Atlanta nonattainment area. For these areas, the 1-h ozone standard was replaced with an 8-h average ozone standard.

Transportation/Land Use Decision Making. Federal and state laws require that the state's transportation program align with a long-range strategy in the *statewide transportation plan* developed by the state department of transportation. This plan is updated every 5 years and maintains a minimum 20-year horizon. As the federally designated Metropolitan Planning Organization for the Atlanta region, the Atlanta Regional Commission (ARC) is responsible for developing a long-range regional transportation plan for the 10-county Metro Atlanta region where nearly half of the state's population resides. The State Department of Community Affairs (DCA) develops a regional comprehensive plan and land use regulations through a "bottom-up" process that is based on the plans of local jurisdictions. DCA's planning staff is also working with ARC staff to assist local governments in meeting the requirements for a transportation element, which is a required part of the comprehensive plans of local governments (Georgia Department of Community Affairs 2004). As indicated, efforts are being made in Georgia to integrate land use decisions which originate in local jurisdictions with state-level transportation planning decisions, with the intent of reducing trips and curbing environmental problems. The mission of the Georgia Regional Transportation Authority (GRTA) and the Governor's Development Council is to improve Georgia's mobility, air quality, and land use practices, to enhance the quality of life of Georgia's citizens, and promote growth that can be sustained by future generations. To achieve this mission, land use practices are being identified to promote more efficient use of transportation investments and restrict choices for citizens to live, work, and play with fewer and shorter trips. Key stakeholders including GDOT, ARC, GRTA, and the State Road and Tollway Authority, have been asked by the Governor to work together to develop a common plan (Georgia Governor Sonny Perdue 2004).

South Korea (Northeast Asia)

Background

The Republic of Korea, commonly known as South Korea, is a country located in East Asia, covering the southern half of the

Korean peninsula, which spans 98,480 sq km, about two-thirds the size of Georgia. To the north, the peninsula borders China and Russia through the Democratic Republic of Korea (often called North Korea), while Japan lies across East Sea to the southeast. South Korea's population, estimated at 47.6 million (2002), is one of the most ethnically and linguistically homogeneous in the world. Korea has a population density of 479 people per sq km. This is more than six times the population of Georgia distributed on a land mass two-thirds the size of Georgia. Seoul, the capital, is a burgeoning megacity (i.e., a city with over 10 million people). As one of the four East Asian Tigers, South Korea has achieved an incredible record of growth and integration into the high-tech modern world economy over the past 30 years. The per capita GNP, only $100 in 1963, exceeded $9,800 in 2002 (i.e., per capita GNI of U.S.$9,930 in 2002) and is equal to that of the lesser economies of European Union, ranking South Korea as the 12th largest economy in the world. Korea has been a major world steel producer since 1990. Also, the nation's shipbuilding and automobile manufacturing industries have reached their peak while its electronics industry is the leading growth sector and an increasingly important foreign exchange generator. With a significant investment in information technology (IT), Korea's IT industry has recorded astonishing growth since the 90s, further augmenting the health of the Korean economy (Wikipedia 2004; Korea.net 2004).

Transportation System

General Characteristics. Roads, handling over 90% of the country's traffic, are the most important type of transportation infrastructure in Korea as well. The total length of the roads has tripled in the past 40 years and measured a total 96,928 km in 2003. Twenty-four expressways measuring 2,778 km in all connect Seoul with provincial cities and towns, covering all parts of the country and placing any destination in Korea within a day's travel. As of 2003, there were 56 routes of national highways measuring 14,234 km in total, making up Korea's trunk road network, together with expressways, providing connections among major cities, ports, airports, and industrial areas. As of 2002, the railway system of Korea encompassed 64 routes spanning 3,129 operational kilometers. The Gyeongbu high speed rail, linking Seoul and Busan, the second largest city on the southeast coast, began service in Korea in April 2004 with the operation of its first high speed train. The subway system network, composed of 12 subway lines (411.5 km), operates in Seoul and three other major cities, and six new lines extending 134.7 km are under construction. Buses and taxis play a vital role in supplementing the subway networks in medium and small cities and meeting transportation needs in the larger cities (Ministry of Construction and Transportation 2004).

To increase the efficiency of transportation operations and improve safety using information technology, the Korean government initiated a high-tech Intelligent Transportation System (ITS) in 1992. Korea has implemented a Freeway Traffic Management System, covering 320 km of expressways, and launched a real-time control system in Seoul. The country is also making efforts to establish an integrated logistics information system for the commercial vehicle operations component of the system.

System Effectiveness. As a result of rapid industrialization, urbanization, and economic growth, South Korea is facing serious transportation problems in its cities. Table 7 shows trends of population and vehicle ownership in Korea. Population growth is being smoothed while vehicle ownership has increased dramatically more than three times in a little over a decade from 3.4 million (1990) to 14 million (2002), owing to the steady rise in income and living standards, expansion of suburbs, and the development of the country's automobile manufacturing industry. Transit system improvements are being made to ameliorate existing conditions.

Table 7. Population and Vehicle Ownership (Korea, 1990–2002)

	Population		Vehicle	
Year	Number (thousands)	Annual Increase (%)	Number (thousands)	Annual Increase (%)
1990	42,869	—	3,395	—
1991	43,296	1.0	4,248	25.1
1992	43,748	1.0	5,231	23.1
1993	44,195	1.0	6,273	19.9
1994	44,642	1.0	7,404	18.0
1995	45,093	1.0	8,469	14.4
1996	45,525	1.0	9,553	12.8
1997	45,954	0.9	10,413	9.0
1998	46,287	0.7	10,470	0.5
1999	46,617	0.7	11,164	6.6
2000	47,008	0.8	12,059	8.0
2001	47,343	0.7	12,914	7.1
2002	47,640	0.6	13,949	8.0
Average annual increase rate		0.9		12.7

Note: Data adapted from the Ministry of Construction and Transportation (2004).

Congestion/Air Quality. The phenomenal increases in vehicular ownership and transport demand create typical urban transportation problems such as severe traffic congestion, air and noise pollution, and serious parking difficulties. Urban transportation policies in Korea are, therefore, in a transitional stage from a supply-oriented to demand-management focus. In addition to continued investment in urban highway networks, city governments are implementing transportation demand management (TDM) plans to control automobile traffic. First, congestion pricing was introduced at the Namsan Tunnel leading to the central business district; second, the traffic impact tax was reduced by 50% for employers who implemented TDM programs, such as carpools; third, higher parking fees have been instituted in congested areas; and fourth, exclusive bus lanes and smart-card fare collection systems have been implemented (Ministry of Construction and Transportation 2004).

The problem of air pollution in Korea is still not very severe relative to the allowable limits set by the Ministry of Environment, as shown in Table 8. However, the levels of particulate matter and nitrogen dioxide have gradually increased because of the high growth rate of automobile ownership. Table 9 depicts the undesirable trends for carbon monoxide, nitrogen oxides, nonmethane volatile organic compounds (VOCs), and sulfur dioxide emissions. All the emission levels increased from 1990 to 1995, and are assumed to still be on the rise owing to continuing growth in vehicle ownership.

Safety. The high rate of road traffic crashes, in conjunction with the absence of order on the road, has long been considered a critical social problem in Korea. Road traffic fatalities were the

Table 8. Air Pollution Trends and Standards (Korea, 1998–2002)

Pollutant	1998	1999	2000	2001	2002
SO_2 (ppm)	0.009 (0.050)	0.009 (0.050)	0.008 (0.050)	0.007 (0.020)	0.006 (0.020)
NO_2 (ppm)	0.020 (0.050)	0.023 (0.050)	0.024 (0.050)	0.025 (0.050)	0.023 (0.050)
O_3 (ppm)	0.020	0.021	0.020	0.021	0.021
CO (ppm)	1.0	1.0	0.9	0.8	0.7
PM_{10} ($\mu g/m^3$)	55 (80)	51 (80)	53 (80)	58 (70)	61 (70)
Pb ($\mu g/m^2$)	0.0959	0.0785	0.0934	0.0669 (0.5)	0.0732 (0.5)

Note: Data adapted from the Ministry of Environment (2003). Values in parentheses represent the average annual limits for each pollutant.

leading cause of death for people under 29 in 2003 (Yang and Kim 2003). The safety level of South Korea's roads is much lower than the average level of safety in OECD countries. As shown in Tables 10 and 11, the country saw 7,185 fatalities in 2003, a fatality rate of 4.4 per 10,000 vehicles compared with the OECD average of 1.9 fatalities per 10,000 vehicles. The major causes of traffic crashes are (1) reckless driving (64%), including drunk driving, speeding, and nonuse of seatbelts; (2) violation of traffic signals (8%); (3) intrusion of median strip (7%); and (4) improper driving at intersections (7%). Compared with the 1995 levels, all three indices (crashes, fatalities, and injuries) show improvements within a relatively short time period through multiple policy interventions including enforcement of penalties for seven risky driving behaviors such as drunk driving and speeding; installation of traffic-monitoring cameras; financial rewards for citizens who reported traffic violations; and the introduction of road safety evaluation and education programs (Yang and Kim 2003).

Social Equity/Other Issues. South Korea needs to address serious social problems caused by population overconcentration in Seoul and inter-regional disparities relative to access to transportation and other services, alleviate continuing environmental damage due to disorderly development, and address supply shortages and deterioration problems associated with the national infrastructures including highway, railway, seaport, airport, and freight distribution systems (Ministry of Construction and Transportation 1999).

Transportation/Land Use Decision Making. The Ministry of Construction and Transportation formulates South Korea's construction and transportation development policies to advance the national economic interest and monitors, guides, and manages multiple functions and tasks including the following: transportation policy, the Comprehensive National Territorial Plan, the land policy and management system, housing supply and construction (Ministry of Construction and Transportation 2004). The National Development Policy Bureau, affiliated with the Ministry of Construction and Transportation, and the Korea Research Institute for Human Settlements are jointly responsible for working together to develop the Comprehensive National Territorial Plan. The Comprehensive National Territorial Plan (2000–2020) articulates five major strategies including *sustaining a healthy and pleasant environment by applying the concept of sustainable development to create a national environment management system wherein environment and development are integrated* (Ministry of Construction and Transportation 1999). In addition, a comprehensive National Transport Network Plan is developed by the Transportation Policy Office of the Ministry, whose main responsibility is coordinating national transport policies. The most recent is the 2000–2019 plan.

Table 9. Air Pollution Trends (Korea, 1990–1995)

Pollutant (1,000 kg)	1990	1995
CO	5234.9	6208.0
NO_x	914.8	1514.9
Nonmethane VOC	871.1	1402.6
SO_2	2429.9	3290.7

Note: Data adapted from Earth Trend (2004).

Table 10. Motor Vehicle Crashes, Fatalities, and Injuries (South Korea)

	Crashes		Fatalities (person)		Injuries (person)	
Year	Crashes (number)	Crashes (per million vehicle km)	Fatalities	Fatalities (per million vehicle km)	Injuries	Injuries (per million vehicle km)
1992	257,194		11,640		325,943	
1993	260,921		10,402		337,679	
1994	266,107		10,087		350,892	
1995	248,865	105.3	16,744	4.4	747,095	140.4
1996	265,052	83.1	12,653	4.0	355,962	111.6
1997	246,452	67.0	11,603	3.2	343,159	93.4
1998	239,721	75.3	9,057	2.8	340,564	107.0
1999	551,060	77.0	18,333	2.6	813,523	112.4
2000	290,481	76.5	10,236	2.7	426,984	112.4
2001	260,579		8,097		386,539	
2002	230,953		7,090		348,184	
2003	240,734		7,185		376,398	

Note: Data adapted from the Ministry of Construction and Transportation (2004) and Yang et al. (2003).

Colombia (South America)

Background

The Republic of Colombia is a country in northwestern South America which spans 1,138,910 sq km, about seven times the size of Georgia. It is bound to the north by Panama and the Caribbean Sea, to the east by Venezuela and Brazil, to the south by Ecuador and Peru, and to the west by the Pacific Ocean. As of the 2002 Census, the population of Colombia was 43.7 million, just over

Table 11. Population Trends (Colombia, 1964-2000)

	Population	
Year	Number (thousands)	Increase rate (%)
1964	17,484,510	NA
1973	20,666,920	18.20
1985	27,853,436	34.77
1993	33,109,840	18.87
2000	39,685,655	19.86

Note: NA=not available. Data adapted from Department of National Statistics (2004).

Table 12. Road Traffic [Motor Vehicles in Use (Colombia, 1997–1999)]

	Passenger cars		Buses		Goods vehicles		Motorcycles	
Year	Number	Percent	Number	Percent	Number	Percent	Number	Percent
1997	1,694,323	NA	126,362	NA	179,530	NA	385,378	NA
1998	1,776,100	4.83	131,987	4.45	183,335	2.12	450,283	16.84
1999	1,803,201	1.53	134,799	2.13	184,495	0.63	479,073	6.39

Note: NA=not available. Data adapted from the International Road Federation (2004).

five times the population of Georgia, making it the third-most populous country in Latin America, after Brazil and Mexico. The country has experienced significant population growth in the past few decades, as depicted by Table 11. The per capita GNI was U.S.$1,820 in 2002. About 20 million people are considered to live in poverty and 10 million in extreme poverty. Movement from rural to urban areas has been heavy as has been the growth in automobiles as shown in Table 12. The urban population increased from 57% of the total population in 1951 to about 74% in 1994. Bogotá, the capital city of Colombia, is one of the densest cities in the world, with 7.7 million people living on 35,000 ha (350 sq km). Ethnic diversity in Colombia is a result of the intermingling of indigenous Indians, Spanish colonists, and Africans. Colombia is a free market economy with major commercial and investment ties to the United States. The country is poised for moderate growth in the next several years, after recovering from a severe recession in 1999 when the gross domestic product (the GDP the total market value of all goods and services produced within the borders of a nation during a specified period) fell by about 5%. The economy suffered from weak domestic demand, austere government budgets, and a difficult security situation. The current government faces economic challenges ranging from pension reform to reduction of unemployment that reached a record 20% in 1999 and may remain high, contributing to extreme inequalities in income distribution. In 1999, the share of agricultural industries stood at 19% in the overall industrial structure; manufacturing industries stood at 26%; and service industries at 55%. Two of Colombia's leading exports, oil and coffee, face an uncertain future; new exploration is needed to offset declining oil production, while coffee harvests and prices are depressed. Besides, the lack of public security is a key concern for investors who are calling for progress in the government's peace negotiations with insurgent groups (The World Bank Group 2002; Wikipedia 2004).

Transportation System

General Characteristics. Transportation mode share data indicates that about half of all trips (46%) are made by bus, 16% by taxi, 15% by automobile, 8% by pedestrian, 8% by bicycle, and 7% by motorcycle (TGI Colombia 2004). Colombia's transportation inventory shows that the railway system of the country spanned 3,340 operational km in 2002, and highway system traversed 110,000 km (including paved and unpaved roadways) in 2000. Trains serve the densely populated areas of Colombia although service is undependable. Buses provide service between cities on the major routes while taxis offer the most reliable public transportation in cities. The country has 1,050 airports (including airports with paved and unpaved runways); the main international airports are El Dorado Airport (Bogotá) and Rafael Nunez Airport. A ferry and a boat service operate between some of the ports and cays in Colombia (World Resources Institute 2004).

Infrastructure. The irregular terrain of Colombia makes the construction of roads and railroads costly. Urban and rural road conditions and maintenance are considered poor (Onursal and Guatam 1997; U.S. Department of State Bureau and Consular Affairs 2004). Basic infrastructure is deteriorating in most major cities in Colombia, and the numerous construction projects initiated to improve this situation contribute significantly to congestion (World Resources Institute 2004).

Safety. Traffic laws are sporadically followed and rarely enforced, and a traffic accident is estimated to occur every ten minutes in Colombia (U.S. Department of State Bureau and Consular Affairs 2004). Road traffic fatalities are ranked as the second leading cause of morbidity and mortality from external causes, exceeded only by homicides. Approximately 20.2% (34,547) of all deaths recorded between 1995 and 1999 were due to road traffic injuries. Pedestrians constitute the largest category of these traffic-related casualties accounting for close to 32% of all injuries and 40% of the deaths from traffic crashes. The problem of road traffic crashes has existed predominantly in the urban areas of Bogotá, Medellin, and Cali. In these main urban centers, pedestrians constituted nearly 68% of road traffic crash victims. As shown in Table 13, over 200,000 road traffic crashes were reported in 2000, representing a fourfold increase from the crashes reported in 1986. Injuries increased fourfold from the mid-13,000s in 1986 to the mid-51,000s in 2000, while fatalities almost doubled from 3,535 in 1986 to 6,551 in 2000. This corresponds to one person dying every 80 min and a mortality rate of

Table 13. Trends on Road Traffic Crashes, Fatalities, and Injuries (Colombia, 1986–2000)

Year	Fatalities	Injuries	Crashes
1986	3,535	13,449	64,289
1987	3,833	15,008	91,723
1988	5,039	19,772	117,933
1989	4,032	18,085	108,506
1990	3,704	16,086	122,112
1991	4,119	18,182	111,462
1992	4,620	21,280	130,304
1993	5,628	33,083	149,940
1994	6,989	45,940	164,202
1995	7,874	52,547	179,820
1996	7,445	50,630	187,966
1997	7,607	49,312	195,442
1998	7,595	52,965	206,283
1999	7,026	52,346	220,225
2000	6,551	51,458	231,974
Total	85,597	510,143	2,282,181

Note: Data adapted from Rodriguez et al. (2003).

Table 14. Air Pollution Trends (Colombia, 1990–1995)

Pollutant (1,000 kg)	1990	1995
CO	7052.7	7006.8
NO_x	420.8	481.2
Nonmethane VOC	1022.3	906.1
SO_2	207.4	246.3

Note: Data adapted from Earth Trends (2004).

15.2 deaths per 100,000 population (Rodriguez et al. 2003). Law enforcement is lacking in some areas resulting in the prevalence of bad driving habits and parked cars occupying public spaces such as sidewalks (Onursal and Guatam 1997).

Congestion/Air Quality. Bogotá, the capital of Colombia, is a highly congested city: the average peak-period speed on the main roads had declined to 10 km/h or lower by 1995. Vehicle ownership is low, at one car per nine inhabitants, as is the number of cars relative to the length of the road network. About 71% of motorized trips are by bus. In addition to the high population density, congestion is to some extent due to the increasing reliance on the automobile for personal movement. Innovative policies have been implemented in Bogotá to transform a car-centered transportation system into a people-oriented one. The goal of TransMilenio, the country's busway project, is to overcome the city's serious transportation problems that were the result of very rapid growth along with very rapid increase in ownership and use of automobiles. This project is based on a strategy to promote non-motorized transport, reduce car use, and increase the use of public transit (Ardila and Menckhoff 2002). Air pollution caused by motor vehicles is a major environmental problem in some parts of Colombia just like in many Latin American urban centers. As shown in Table 14, the emission levels of carbon monoxide, nitrogen oxides, and sulfur dioxide increased significantly from 1990 to 1995 with growth rates between 15 and 20%.

Transportation/Land Use Decision Making. The Ministry of Transportation is responsible for formulating the policies of the Colombian National Government in matters of transit, transportation and infrastructure. The Ministry periodically works collaboratively with the Institute of Urban Development (IDU), whose mission is to execute infrastructure maintenance and improvement projects to achieve sustainable development. The IDU monitors a transportation subsystem within an institutional framework regulated and controlled by the Ministry of Transportation. The Ministry of Transportation has also enacted Plan 2500. The most ambitious road project in the history of Colombia, Plan 2500 will pave 2,500 km of routes in different regions in Colombia. The Ministry has gained the participation of the Ministry of Property, the National Department of Planning, and the private sector economic and industrial groups led by CAMACOL, Colombia's union for industrial construction.

Ghana (West Africa)

Background

The Republic of Ghana commonly known as Ghana is located in West Africa bordered to the south by the Gulf of Guinea (Atlantic Ocean), the north by Burkina Faso, the west by Cote d'Ivoire and the east by Togo. About 1 1/2 times the size of Georgia, Ghana has a total area of 239,460 sq km and had a population of about 20.5 million in 2003. The per capita GNI was $270 in 2002.

Table 15. Population and Population Growth Rates (Ghana, 1950–2000).

	Year				
Demography	1985	1990	1995	2000	2005
Total population (hundreds)	12,838	15,018	17,338	19,928	22,818
Total population growth rate (%)	NA	3.14	2.87	2.79	2.71

Note: NA=not available. Data adapted from United Nations Habitat (2004).

Ghana's population is ethnically diverse with at least 75 distinguishable languages (Encyclopedia Britannica Online 2004). About 31% of the population is below the poverty line (Nationmaster.com 2004). The country has a relatively high population growth rate. As shown in Table 15, the population has increased steadily over the last 25 years with 2.9% of average quinquennial (5-year) growth rate in the period from 1985 to 2000. About 36% of the population was urbanized in 2001, up from 30% in 1975. The country has an abundance of natural resources, primarily gold, timber, industrial diamonds, bauxite, manganese, fish, rubber, and hydropower. Agriculture accounts for 45% of the GDP and cocoa and timber account for 35% of the country's exports. The GNP growth has increased steadily from 2.0% in the early 1990s to a per annum rate of 4.7% (1995–1997), with a projected growth of 4.4% through 2010. Inflation has been high in recent years with rates such as 23.6% in 2003 (U.S. Department of State 2004); unemployment rates have also been high (20% in 1997) (IndexMundi 2004). Accra is both the administrative and commercial center of Ghana. Its population of 1.8 million is growing at a rate of 4%, and occupies around 2% of Ghana's total area. Accra's economy contributes between 15 and 20% of the country's GDP, and accounts for 10% of employment in Ghana (NRTEE 2004).

Transportation System

General Characteristics. Among the major modes of transport in the country, the road sector is of considerable importance and accounts for 94% of freight and 97% percent of passenger traffic (Sesime Adanu, unpublished). The country's transportation system consists of a 40,000 km road network consisting of 13,433 km of trunk roads, 24,000 km feeder roads, and over 22,000 km of urban roads; two large deep water ports, which handle about 7 million tons of import and export traffic; and a 944 km railway system serving the southern part of the country. Ghana has one international airport, and 8 regional airports and airstrips spread throughout the country (The World Bank Group 2002). Transportation is a major source of sustenance for the Ghanaian economy. Despite its importance, however, the sector is faced with several problems, such as deplorable road conditions, poor vehicular maintenance, and poor law enforcement, all of which have contributed to very high crash rates in Ghana.

Infrastructure/Equity. The poor road network is mostly seen in the disparity between rural and urban areas, where almost all the regional capitals and most of the district capitals have accessible roads while most rural areas have deplorable road conditions. The end result is that the produce, in particular, major exportable perishable commodities on which the country's economy depends, can be subject to decay in the inaccessible areas, and create disincentives for farmers to produce. Not only

Table 16. Trends in Road Traffic Crashes, Casualties, and Vehicles Involved (Ghanna, 1994–1998)

Year	Crashes	Fatalities	Injuries	Number of vehicles involved
1994	6,580	824	7,663	9,995
1995	8,314	1,026	9,105	12,916
1996	8,489	1,050	9,903	13,368
1997	9,914	1,014	10,431	15,619
1998	10,715	1,362	11,405	16,892
Total	44,012	5,276	48,507	68,790
Percent change	62.8%	65.3%	52.8%	69%

Note: Data adapted from Afukaar et al. (2003).

are the roads bad, but there also exist inequalities in motorable and accessible roads in the country, attributable mainly to economic resource availability in the different areas. Lack of accessibility for vital destinations such as jobs, schools, markets, and health care has affected development activities in inaccessible areas (Sesime Adanu, unpublished). Besides, many of the roads have inadequate signs or pavement that is not equipped to handle the traffic. The country also lacks an effective public transportation system.

Safety. One of the main problems facing Ghana is increasing road traffic fatalities reflected in the number of lives lost every month. The Public Agenda newspaper (2003) revealed that 150 people die in the country every month through road accidents alone (Sesime Adanu, unpublished). According to 1994–1998 police data, road traffic crashes were a leading cause of death and injuries in Ghana, beside occupational injuries which involve non-mechanized farming and ethnic conflicts. Table 16 shows recent trends in road traffic crashes, deaths, and injuries and Table 17 shows crash and injury rates per 100,000 inhabitants. The majority of road traffic fatalities (61%) and injuries (53%) occurred on roads in rural areas. About 58% more people died on roads in rural areas than in urban areas, and generally more severe crashes occurred on rural roads compared with urban roads. The number of reported crashes increased by 63 percent between 1994 and 1998. Road traffic injuries increased by 49% and deaths by 65%. In the same period, the number of vehicles involved in crashes increased by 69%.

The nature of transport-related deaths and injuries in both urban and rural areas is fundamentally different from that in developed countries: in developed countries, crashes involving occupants of private vehicles predominate and pedestrian injuries make up a smaller percentage of all transport-related injuries (Afukaar et al. 2003). In Ghana, pedestrian deaths constitute the largest category (46%) of fatalities among all road users, followed by occupants of buses and minibuses. High driving speeds of poorly maintained passenger-ferrying vehicles on generally badly deteriorated roads, coupled with the lack of emergency medical services, have combined to increase fatalities on rural roads (Afukaar et al. 2003).

Table 17. Crash and Injury Rates per 100,000 Population (Ghana, 1994–1998)

Region	Injury crash rate	Fatal injury rate	Serious injury rate	Slight injury rate	All casualties rate
Whole country	139.9	28.7	102.1	161.3	292.1

Note: Data adapted from Ghana Statistical Service (2004).

Table 18. Air pollution Trends (Ghana, 1990–1995)

Pollutant (1,000 kg)	1990	1995
CO	2227.1	2319.7
NO_x	105.9	112.9
Nonmethane VOC	204.2	218.7
SO_2	29.7	32.4

Note: Data adapted from Earth Trends (2004).

Congestion/Air Quality. Air quality is deteriorating in urban areas, particularly in the capital city of Accra and the surrounding metropolitan area. Ghana's urban population, especially in Accra, has burgeoned, with annual growth rates estimated as high as 4%. The corresponding rise in vehicle transport has caused major traffic congestion and excessive wear and tear on the road network. Road travel, whether motorized or nonmotorized, poses difficulties that place considerable hardship on the urban poor (The OPEC Fund for International Development 2004). Rapid increases in car ownership coupled with poor land use planning, inadequate road space, lack of regulated parking systems, uneducated use of the road by pedestrians, and bad driving behavior of motorists have also combined to produce serious congestion, especially in Accra (Abane 1993). Sprawl is evident in several parts of the expanding Accra metropolitan area. As shown in Table 18, the total emissions of carbon monoxide, nitrogen oxides, nonmethane VOCs, and sulfur dioxide increased at relatively high rates from 1990 to 1995, and are expected to be on the rise owing to continuing growth in the Accra metropolitan area.

Land Use/Transportation Decision Making. The Ministry of Roads and Transport is responsible for the development and maintenance of transport infrastructure and the provision of transport services for all modes of transport in Ghana. The Ghana Roads Sector Development Program aims at achieving sustainable improvement in the supply and performance of roads as well as road transport services in a regionally equitable manner. The goal is to increase Ghana's competitiveness in foreign trade and promote linkages in domestic markets which are crucial for rapid and sustained growth (The World Bank Group 2002). Ghana has undertaken three transportation projects that have contributed to the success of the country's economic recovery program. The projects, implemented from 1987 to 1998, rehabilitated economically important roads and instituted maintenance programs to prevent road deterioration (Graduate School of Architecture and Preservation 2004). There is, however, the need to integrate land use and transportation decisions better to gain better control over congestion, sprawl, and the associated air quality problems in the Accra metropolitan area. Vision 2020 is Ghana's road map to achieving middle-income country status by the year 2020. The basic objectives of Vision 2020 are to reduce poverty, increase employment opportunities and average incomes, and reduce inequities in order to improve the general welfare and the material well being of all Ghanaians. In the Vision 2020 framework, the fundamental policy objective of the transport sector is to establish an efficient, modally complementary, and integrated transportation network for the movement of people and goods at the least possible cost within the country. This policy is meant to support Ghana's Gateway Program, a program intended to attract foreign

investment and establish Accra as West Africa's regional distribution and transshipment center (The Official Ghana Education Homepage 2004).

Synthesis of Findings

A summary of key transportation and sustainability issues for Georgia, South Korea, Colombia, and Ghana is shown in Table 19, and potential areas for improving transportation sustainability for the four cases are presented in Table 20. The cases point to some of the similarities and differences in transportation sustainability issues in countries at different levels of socioeconomic development. The sections below draw out some of these similarities and differences.

All the four areas studied were characterized by rapid population growth in their major metropolitan areas, resulting largely from rapid urbanization (in the developing countries) or population influxes from other urban and nonurban areas, or other countries, to metropolitan areas with booming economies (in the developed countries). All four cases were also characterized by rapid growth in the demand for vehicular travel and the actual vehicle kilometers traveled. Thus, congestion, with its debilitating effects, was shown to be a problem independent of the socioeconomic status of the areas studied; however, it was also a sign of booming economies in the metropolitan areas of the higher-GNI countries (Atlanta, Seoul). The higher-GNI areas had begun to address congestion using ITS (Atlanta, Seoul) and by shifting from supply-oriented to demand management policies (Seoul). Air quality, like congestion, was a major issue independent of socioeconomic status. While regulatory standards for managing air quality were found in the developed countries, no standards were found for the developing countries. In addition to the debilitating effects of congestion, the lower-GNI countries faced problems with poor and inadequate physical infrastructure, and the need for infrastructure expansion and maintenance were also considered to be important issues in South Korea.

Safety was a major issue in all the four cases. Roadway crashes were found to be a major cause of death in South Korea, Colombia, and Ghana. The cases indicated that roadway safety issues tended to be automobile-centered in developed countries and pedestrian-centered in developing countries. In addition, while crash fatalities were decreasing in Georgia and South Korea, they were increasing in Colombia and Ghana. The developing countries also seemed to have some issues with law enforcement exacerbating their safety problems. The lack of emergency medical services in Ghana also compounded the country's safety problem. The fact that safety is a priority for all countries, independent of economic status, levels and trends in highway crash fatalities, indicates that safety standards are likely to vary widely in the quest for sustainable transportation depending on the present status of transportation safety in a particular country or state. A significant part of the causes of crashes was found to be behavior-related, e.g., bad driving habits, poor vehicle maintenance, lack of appropriate laws, and inadequate law enforcement. The fact that roadway crashes were considered to be a major cause of death in three out of the four areas studied, and the trend in roadway fatalities was on the rise in the two developing countries studied, is an indication that roadway safety is or ought to be a priority in initiatives to address transportation sustainability. The opposite trends in highway crash fatalities in the developing and developed economies, and the different levels of activity relative to regulating air quality indicate that while across-the-board standards may be necessary to promote movement toward transportation system sustainability in the international community, it may also be difficult to gain consensus for such standards on various important issues given the wide variation in the present status and trends for various transportation sustainability indicators. The fact that crash rates were generally caused or exacerbated by the behaviors of system users indicates that measures for changing behaviors also ought to play an increasingly important role in improving the safety of highway systems around the world. Korea's recent successes with using behavioral-related policies to reverse the trends in highway fatality crashes point to the potential effectiveness of coupling behavior-related policies with infrastructure, operational and information technology improvements, as well as other measures to address transportation system safety.

In all the cases, equitable access to adequate transportation was considered an issue as social equity is one of the most important elements in moving toward sustainability. It is important that sustainability indicators explicitly capture equity given that several economic indicators (e.g., GDP) reflect only the "average" of conditions but not the variance or discrepancies among populations. It is possible for example that continuing economic development in various countries may tend to increase the gap between higher-income and lower-income populations, which would not be captured by the use of average indicators. Equity-related indicators such as access to basic social and economic services for those without cars, affordability of public transit services especially for lower income groups, and the quality of transit with respect to the mobility impaired, can capture social equity across different income levels, age and other demographic categories. Equity issues have arisen along the lines of socioeconomic class (Georgia, South Korea, and Ghana), race (Georgia), or urban/rural status (Georgia, Colombia, and Ghana). Georgia's fatalities on rural two-lane roads have been significantly higher than fatalities in all other categories. In South Korea, regional disparities were found relative to access to transportation and other socioeconomic resources. Both Colombia and Ghana have experienced relatively high pedestrian fatality rates. In Colombia, Bogotá, Medellin, and Cali (major cities) have experienced high pedestrian fatality rates. In Ghana, pedestrian deaths constituted the largest category of fatalities among all road users, followed by occupants of buses and minibuses; and the majority of road traffic fatalities and injuries occurred on roads in rural areas.

While no mandates were found for integrated land use and transportation planning in all the cases, Georgia was making some efforts toward integrating land use and transportation planning, South Korea had developed a comprehensive land use/transportation plan, and Colombia's Ministry of Transportation had taken the initiative to work with other agencies, including agencies with control over land use decisions, in order to make more effective decisions.

While several data were found on the physical extent of transportation infrastructure assets in all cases, little was found to indicate how effectively and efficiently the existing transportation system was serving the country or state's residents by providing them with access to their basic needs. Such measures would strengthen our understanding of the overall effectiveness of the transportation/land use system.

South Korea's remarkable transition from low-income to high-income status in the past three decades offers an excellent example for low-income economies that such transitions are feasible and involve significant and sustained investments in infrastructure and information technology, as well as the political will to imple-

Table 19. Summary of Key Transportation and Sustainability Issues

Issue	System attributes case			
	Georgia (United States)	South Korea	Colombia	Ghana
Effectiveness/ efficiency	Severe traffic congestion in metropolitan Atlanta Demand management through ITS technologies, HOV lanes, public education initiatives to promote carpooling, telecommuting, etc.	Severe traffic congestion in Seoul Demand management through ITS technologies, congestion pricing, traffic impact taxation; higher parking fees in congested areas; exclusive bus lanes	Bogotá capital city is highly congested Bus is the predominant mode of transportation, and taxis provide the most reliable service in the cities Train service is undependable Transmilenio Busway Project implemented to transform car-centered Bogots to pedestrian-centered city Poor infrastructure conditions	Severe congestion in Accra metropolitan area Lack of effective public transportation system Poor infrastructure
Safety	Downward trend for fatality and injury crashes Highest fatalities occur on rural two-lane road	Downward trend for fatality and injury crashes Road traffic fatalities leading cause of death for people under 20 (2003)	Upward trend in highway crash fatalities Road traffic fatalities second leading cause of death next to homicides: one traffic crash occurs every 10 min Urban pedestrian fatalities constitute highest category of traffic fatalities	Upward trend in highway crash fatalities Road crashes are a leading cause of death in the country; the majority of which occur on roads inn rural areas Pedestrain deaths constitute the largest category of road traffic deaths followed by buses and minibuses
Economic	High income status Commercial transportation positively impacts agricultural industry	High income status Remarkable growth in GNI over the past 30 years is positively associated with transportation development made over the past decades	Middle-income status High poverty rate is positively associated with poor infrastructure conditions High rate of urban pedestrian deaths	Low-income status Significant percentage of agricultural exportable produce decay due to poor road access: disincentive for farmers to produce
Social equity	High fatality rates on rural two-lane highways	Inter-regional disparities in accessibility and mobility	High rate of urban pedestrian deaths	Wide disparities in road access and infrastructure condition in urban and rural areas
Environmental	Poor air quality in metropolitan Atlanta with associated respiratory health effects	Air pollution in Seoul: increasing trends in particulate matter and nitrogen dioxide emissions Noise pollution in Seoul	Increasing trends in nitrogen oxides and sulfur dioxide emissions	Rapidly increasing trends in carbon dioxide, nitrogen oxides, and nonmethane VOCs in Accra
Decision making	No formal mandate found for integrated land use/ transportation decision making; however, efforts have been made to coordinate the planning activities of land use and transportation agencies	No formal mandate found for integrated land/use transportation decision making; however, there has been the development of the National comprehensive Plan including land use and transportation elements	No formal mandate found for integrated land use/ transportation decision making; however, the Ministry of Transportation is involving several agencies in its decision making	No formal mandate found for integrated land use/transportation Planning
Other related issues	Sprawl and its impact on poor air quality Opportunities for integrating land use and transportation planning better in metro Atlanta	Disorderly development resulting in environmental damage	High level of poverty Rapid urbanization Poor enforcement of traffic laws Public security issues Extreme inequality in income distribution Leading exports facing uncertain future	High level of poverty Poor infrastructure conditions Poor law enforcement Lack of emergency medical services Poor land use planning in metropolitan areas

Table 20. Example of Potential Areas for Transportation Sustainability Improvements [Georgia (United states), South Korea, Colombia, and Ghana]

Georgia (United States)	South Korea	Colombia	Ghana
Implement more effective and efficient public transportation systems	Improve road safety by effectively ordering the road and changing driver behavior	Improve pedestrian safety especially in urban areas	Improve roadway and pedestrian safety
Decrease automobile demand by more actively promoting carpooling, telecommuting, etc	Focus more on effective congestion management, e.g., immediate incident management	Improve law enforcement	Improve emergency medical service
Improve safety measures especially on rural two-lane roads	Minimize inter-regional disparities in accessibility and mobility	Implement more reliable public transportation systems	Improve law enforcement
Integrate land use and transportation planning better in metro Atlanta	Implement more advanced environmental policy pertaining to air noise pollution	Improve infrastructure condition	Implement effective public transportation system
	Integrate land use and transportation planning more effectively	Enforce traffic and environmental laws more adequately	Improve road accessibility especially for agricultural incentives
			Improve infrastructure condition particularly in rural areas
			Improve land use and planning in metropolitan areas

ment behavioral-related policies that improve the quality of the transportation environment. It also indicates that the drivers for congestion and associated air quality issues in metropolitan areas (e.g., high population growth rates, rapid urbanization, and pressures to relocate to areas with booming economies) do not automatically disappear with successful economic growth, and must be proactively managed simultaneously as economic growth is pursued, in order to preserve regional quality-of-life gains.

Colombia's example with the Transmilenio Project in Bogotá is demonstrating the feasibility of transforming a city from an auto-centered to a pedestrian-oriented city and the importance of effective public transportation systems for addressing some of the congestion and air quality problems in metropolitan areas, particularly in areas with adequate population densities to support effective public transportation. As rapid urbanization occurs in developing countries, and rapid metropolitan population growth continues to occur in developed economies, both of which continue to create increased population densities to support public transportation, the development of effective public transportation (less-developed economies) and improvement of the convenience of existing public transportation systems (more-developed economies) grow to be more feasible options for transforming neighborhoods from auto-centered to public transportation-centered systems.

All four cases indicate that there is a serious need to consider taking formal steps to integrate the transportation and land decision making processes better, in order to address more effectively such issues as sprawl (Atlanta, Accra), disorderly development (Seoul), and the effective organization of highly populated urban areas (Bogotá). Rapid population growth in the Atlanta and Seoul metropolitan areas, and rapid urbanization in Bogotá and Accra, as well as the increasing rate of vehicle ownership in these areas, all point to an urgent need for institutions or institutional mechanisms that are better equipped to plan more comprehensively including using land use controls to gain a better handle on a broader range of influences on metropolitan quality of life.

Implications and Conclusions

The findings of this study have important implications for the development of priorities and standards for progress toward achieving transportation sustainability within the international community. First, the data available on different aspects of transportation systems vary widely in adequacy and completeness. No data were found for any of the cases capturing the relative levels of accessibility that the population had to basic services and amenities, indicating that it would be difficult to measure gains in accessibility that occur without improvements in mobility, which is a major area of opportunity for progress toward sustainability. The data on the adequacy of the transportation system were largely mobility focused. In addition, metrics for data on particular attributes, e.g., safety, were different for the different cases. For example, while crash fatalities were being measured as a function of vehicle kilometers traveled in Georgia they were being measured as a function of the number of vehicles in South Korea, in Ghana as the total number of injuries or fatalities per a standard number of people, and in Colombia by the total number of fatalities or injuries per year. Thus, safety gains or losses would be more difficult to capture using the data of the low/medium-income countries. Data standards to facilitate comparability would support progress toward sustainability.

The widely different socioeconomic conditions represented by the four case studies indicate why it would be difficult to develop uniform standards for attaining sustainability within the international community and seem to suggest that "movement toward sustainability" may be a more realistic objective than "achieving sustainability." In practice, therefore, the fact that there are few widely accepted standards for what would constitute sustainability should not be a major obstacle for entities interested in taking steps to move toward sustainability because different policy, plan, program and project actions can be classified objectively as sustainability gains or losses along the lines of the commonly accepted criteria for sustainability (e.g., effective/efficient/safe access, economic growth, environmental, and social equity, for transportation). At the same time, the commitment of various entities (local jurisdictions, states, countries, nations, and the global community) to sustainability is partially dependent on the commitment of their neighboring entities to move toward sustainability, because of the existing threat of "tragedy of the commons" inclinations.

First, this would seem to suggest that certain groupings of entities may provide better forums for achieving consensus on standards to move toward sustainability: entities that have similar

socioeconomic conditions, and thus share feasible goals, priorities, and constraints. For example, while stabilizing or reversing the trends in roadway fatalities may be plausible interim targets for Colombia and Ghana, such targets are not relevant for South Korea and Georgia, and thus lumping these four entities together in the development of safety standards for sustainability may not be a very worthwhile endeavor. Success in building consensus for standards would entail a convergence of minds, which may more likely occur among entities that have similar issues to contend with. Second, it would also seem to suggest that, for practical purposes, standards may be movable targets with associated time frames rather than fixed endpoints anchored at some infinite points in time. A plausible objective may be to move "regions of similar status and constraints" toward sustainability through consensus-based interim targets that are subject to change over time. The term region is used in this context to capture entities with similar existing socioeconomic conditions with respect to achieving sustainability in a particular domain, e.g., transportation. Thus, such regions may be geographically contiguous but not necessarily so. For example, entities with vehicle fatalities on the rise are natural members of a region that would be interested in reversing trends in roadway fatalities. Thus, the levels of comparability among a particular group of entities would have a direct impact on their ability to reach consensus on particular targets for sustainability in agreed-upon time frames.

These ideas suggest potential differences in the types of forums that could be successfully adopted to develop *intra-regional standards* in contradistinction with *inter-regional standards*. It would seem that the successful development of intra-regional standards (interim targets) would need to be more sensitive to the needs of members of a particular region. Inter-regional agreements, on the other hand, could be negotiated among regional representatives on issues or "bundles of issues" that are not necessarily similar but offer opportunities for give-and-take, taking into consideration the different needs and interim goals of the participating regions. Under such a framework, standards that cut across regions would not necessarily be *similar* for all regional entities involved, but rather *acceptable* based on a mindset of tradeoffs brought to the negotiation table and an understanding that the prevailing conditions in different regions can be significantly different.

One may also argue that some sustainability issues have farther-reaching influence than others, and that in developing standards, the former would be more important across regions than within regions. For example, vehicle emissions may be considered farther-reaching than crash fatalities in the quest for acceptable across-the-board standards, because the impacts of the former on neighboring entities are potentially more significant than the latter. Distinguishing among indicators that have intra-regional versus inter-regional implications could be helpful for understanding how much of a driver regional commonalities would be in the successful development of standards for sustainability, and thus for crafting issues or "bundles of issues" that are more likely to gain consensus at appropriate levels (local, national, regional, global) of decision making, while temporarily managing at more disaggregate level issues that are less likely to gain across-the-board consensus.

These ideas are intended to offer food for thought to the broader community interested in finding more successful models to develop standards for promoting movement toward sustainability in the international community. Perhaps different regionally-based standards that are perceived as equitable across regions stand more of a chance of being adopted than across-the-board standards that may fail to acknowledge the needs and constraints of various entities while catering to others (from the very nature of the wide scope of conditions present in different socioeconomic contexts). A model where standards are crafted as movable targets based on mutually agreed upon time frames and where entities' memberships in regions can change, depending on the changes in their sustainability status, may offer more appropriate incentives for accelerated movement toward sustainability among a broader scope of entities with widely different socioeconomic conditions and constraints.

Several issues worth considering, while beyond the scope of this paper, remain important subject material to advance progress toward sustainability. Particularly important are the effects of population densities on achieving and measuring transportation sustainability (in particular, megacities such as Seoul, Los Angeles, and Lagos may offer a unique set of challenges for the development of sustainable transportation systems); understanding causes and drivers of sustainability and nonsustainability in transportation systems, understanding the relationships between implemented economic/infrastructure policies and the resulting system outcomes (e.g., safety, congestion, air quality); and appropriate indicator sets for measuring progress toward sustainability at various levels of socioeconomic development.

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